MEDIUM ACCESS CONTROL FOR RETRO-REFLECTORS

TECHNICAL FIELD

[0001]   The invention relates to the field of communications and, more particularly, to systems and methods that send and receive data using modulated retro-reflectors.

BACKGROUND OF THE INVENTION

[0002]   Systems that use modulating retro-reflectors for communications are well-known. One existing system employs modulating retro-reflectors to communicate optically and provides secure, high-speed data communications. However, existing communications systems that employ modulating retro-reflectors do not provide a flexible access control method for controlling communications among a probe device and a group of retro-reflectors, such that each of the retro-reflectors may receive schedule information regarding when respective retro-reflectors may be interrogated for data or · may receive data. Further, a need exists for a system that permits a schedule for exchanging data between the probe device and any one of the retro-reflectors to be adjusted based on conditions, such as an amount of data to send or urgency of data.

SUMMARY OF THE INVENTION

[0003]   Systems and methods consistent with the principles of the invention provide a medium access control method for use in communication systems that employ retro-reflectors.

[0004]   In a first aspect of the invention, a communication method is provided for a retro-reflector device. The retro-reflector device receives a first frame encoded in an

input beam. The retro-reflector device creates and sends a second frame in a first reflected beam formed by the retro-reflector device reflecting the input beam along a patch closely aligned with a path of the input beam. At least one of the first frame and the second frame includes medium access control information.

[0005]   In a second aspect of the invention, a retro-reflector device is provided. The retro-reflector device includes a receiving portion configured to receive an incoming beam from a device and to decode a first frame included in the incoming beam. The first frame includes schedule an indication of a next time for the retro-reflector device to receive an incoming beam.

[0006]   In a third aspect of the invention, a device that is configured to send an incoming beam to at least one retro-reflector device is provided. The device includes a transmitter and a receiver. The transmitter is configured to provide a carrier as an incoming beam to at least one retro-reflector device and to encode a first frame onto the carrier. The receiver is configured to receive and decode a reflected beam, including a second frame, from the at least one retro-reflector device. One of the first frame and the second frame includes medium access control information.

[0007]   In a fourth aspect of the invention, a system is provided for controlling communications. The system includes a probe device and a group of retro-reflector devices. The probe device is configured to send a first frame modulated onto a carrier as an incoming beam. Each of the retro-reflector devices is configured to encode and modulate a second frame onto a reflected beam, responsive to receiving the first frame in the incoming beam, and transmit the second frame to the probe device. One of the first frame and the second frame includes medium access control information.

[0008] In a fifth aspect of the invention, a retro-reflector device is provided. The retro-reflector device includes means for receiving and decoding a first frame in an incoming beam from a remote device and means for forming a reflected beam by reflecting the incoming beam along a path closely aligned with a path of the incoming beam and for encoding a second frame in the reflected beam. One of the first frame and the second frame includes medium access control information.

[0009] In a sixth aspect of the invention, a machine-readable medium is provided. The machine-readable medium has recorded thereon, instructions for at least one processor of a retro-reflector device. When the instructions are executed by the at least one processor, the at least one processor is configured to: receive an incoming beam from a remote device and decode a first frame included in the incoming beam; and form a reflected beam by reflecting the incoming beam along a path closely aligned with a path of the incoming beam and encode a second frame in the reflected beam. At least one of the first frame and the second frame includes medium access control information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an embodiment of the invention and, together with the description, explain the invention. In the drawings,

[0011] Fig. 1 illustrates an exemplary system consistent with principles of the invention;

[0012] Figs. 2A and 2B show a prior art retro-reflector that may be used in implementations consistent with the principles of the invention;

[0013] Fig. 3 illustrates an exemplary retro-reflector device that may be used in implementations consistent with the present invention;

[0014] Figs. 4A and 4B show exemplary formats of an incoming frame and an outgoing frame, respectively, used in communications between a remote device and a retro-reflector; and

[0015] Figs. 5 and 6 illustrate exemplary processing in implementations consistent with the principles of the invention.

DETAILED DESCRIPTION

[0016] The following detailed description of the invention refers to the accompanying drawings. The same reference numbers in different drawings may identify the same or similar elements. The following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims and equivalents.

Operating Environment

[0017] Fig. 1 illustrates an exemplary system 100 consistent with the principles of the invention. System 100 may include a probe device 102 and a group of retro-reflectors 104-1 to 104-5 (collectively referred to as 104). It will be appreciated that a typical system could include more or fewer devices than are shown in FIG. 1.

[0018] Probe device 102 may include any conventional device capable of transmitting a beam to retro-reflector 104 and receiving a reflected beam from retro-reflector 104. The beam may be implemented by light, radio frequency waves, acoustic waves, or any other mechanism that can act as a carrier and be reflected. When probe device 102 desires to interrogate retro-reflectors 104, probe device 102 may generate an

incoming beam 106 and direct incoming beam 106 toward any one of retro-reflectors

104. A receiving retro-reflector 104 may encode and modulate data onto a reflected

beam 108 reflected back to probe device 102. Probe device 102 may receive and decode

the data transmitted via reflected beam 108.

[0019]　Probe device 102 also may send data to any of retro-reflectors 104 by

transmitting a modulated incoming beam 106 to any one of retro-reflectors 104. Probe

device 102 may modulate incoming beam 106 by, for example, on-off keying, when the

beam includes light waves. Retro-reflector 104 may sense the modulation and decode the

"zeros" and "ones" encoded in incoming beam 106.

[0020]　Probe device 102 may include one or more processors (not shown) and a

memory (not shown) for processing information sent to and received from retro-reflector

104. Retro-reflectors 104 may be attached to, for example, sensors, actuators or network-

enabled computers.

[0021]　System 100 may be outdoors. For example, probe device 102 may be located

in, for example, an aircraft or a satellite, and retro-reflectors 104 may be located, for

example, on the ground, in trees, on top of buildings, etc. Alternatively, system 100 may

be indoors. For example, probe device 102 may be located in a ceiling mount and retro-

reflectors may be attached to various points of a room or hallway, such as, for example,

on thermometers, vibration sensors, microphones, controls or actuators, etc.

[0022]　Although system 100 is described as using an optical retro-reflector, retro-

reflectors that reflect and modulate a number of media may be used. For example, retro-

reflectors 104 may receive and modulate beams of acoustic waves, radio frequency (RF)

waves, or any other carriers that can be reflected, including light waves.

Exemplary Configuration

[0023] A number of different types of retro-reflectors 104 may be used in implementations consistent with the principles of the invention. Figs. 2A-2B illustrate an exemplary prior art retro-reflector 104 that may be used in implementations consistent with the invention. Retro-reflector 104 may include any type of well-known arrangement capable of reflecting incoming beam 106 back as a reflected beam 108 in such a way that reflected beam 108 follows a path very closely aligned with that of the incoming beam 106. Retro-reflector 104 may be, for example, a cat's eye retro-reflector, as shown in Figs. 2A-2B. Retro-reflector 104 may include a lens 202 and a modulator/receiver, such as a pixellated modulator/receiver 204. Lens 202 may have a field of view (FOV) of, for example, 30 degrees. In exemplary retro-reflector 104 of Fig. 2A, incoming beam 106 may be, for example, light waves that may have a wavelength of about 1550 nanometers.

[0024] Pixellated modulator/receiver 204 may include a group of quantum wells 206 arranged in pixels, as illustrated in Fig. 2B. Each quantum well 206 of pixellated modulator/receiver 204 may have an area of, for example, 1 square millimeter, which can be made to have a reflective or a non-reflective surface. Thus, pixellated modulator/receiver 204 may modulate data onto a reflected beam 108 by changing the reflectivity of individual quantum wells 206. For example, a reflective surface of quantum well 206 may indicate a "1" value, while a non-reflective surface may indicate a "0" value, or vice versa. A remote device, such as probe device 102, may provide incoming beam 106 and may observe modulated reflected beam 108.

[0025] Each quantum well 206 may include a positive-intrinsic-negative (PIN) diode (not shown) and therefore, may act as a photodetector that can sense whether it is being

struck by incoming beam 106, which may be a high power optical beam from a laser or

other source. As previously mentioned, probe device 102 may modulate data by, for

example, on-off keying, in which on (the presence of incoming beam 106) may represent

a "1" value and off (the absence of incoming beam 106) may represent a "0" value, or

vice versa. Retro-reflector 104 may sense the modulation via the PIN diodes of quantum

wells 206.

[0026]   Fig. 3 illustrates an exemplary retro-reflector device 302 that may be used in

implementations consistent with the principles of the invention. Retro-reflector device

302 may include retro-reflector 104, a modulator 310, a demodulator 312, a clock 315, a

memory 320, a processor 325, and a power source 350.

[0027]   Retro-reflector 104 may receive messages via incoming beam 106 and may

transmit messages via reflected beam 108, as previously discussed. Incoming beam 106

may include a carrier signal generated at a distant communicating device, such as distant

probe device 102 (Fig. 1). Incoming beam 106 may be, for example, implemented by

light, radio-frequency waves, acoustic waves, or any other mechanism that can act as a

carrier and be reflected.

[0028]   Reflected beam 108 represents the reflection of incoming beam 106 after

being reflected by retro-reflector 104. It will be appreciated that reflected beam 108 may

be, more or less, a full strength reflection of incoming beam 106, a substantially

weakened (in amplitude) reflection, or any variation in between. Incoming beam 106

may also be altered in other ways, e.g., in phase or in polarity. Furthermore, reflected

beam 108 may be entirely absent, i.e., when retro-reflector 104 is disabled. These

alterations in reflected beam 108 may be used to encode retro-reflector's 104

transmission of bits.

[0029]   Modulator 310 may include any type of conventional modulator capable of

modulating the state of retro-reflector 104, for example, via quantum wells 206 of a cat's

eye retro-reflector, so as to vary reflected beam 108 in such a way to allow for the

detection of the different variations. In its simplest form, modulator 310 might represent

a 0 bit as a non-reflected beam, and a 1 bit as a reflected beam. This is a simple on/off

type of scheme. More complex modulation techniques are also possible (e.g.,

brighter/darker, coherent/incoherent, changes in phase, changes in polarization, etc.).

Such modulation techniques are well known in the communications field.

[0030]   Demodulator 312 may include any type of conventional demodulator capable

of demodulating data encoded in incoming beam 106. As described above, incoming

beam 106 may be modulated via, for example, on-off keying. Thus, for example, PIN

diodes (not shown) within each quantum well 206 may detect the presence or absence of

incoming beam 106. Signals representing the presence or absence of incoming beam 106

may be input to demodulator 312 from each quantum well 206. Demodulator 312 may

then reconstruct data from the signals.

[0031]   Clock 315 may include a conventional clocking device, such as a quartz

oscillator, that may provide timing information to modulator 310 for encoding bits for

transmission and may provide the timing information to demodulator 312 for decoding

received signals from quantum wells 206. In particular, clock 315 may provide an

indication of the time duration needed for transmitting a bit, e.g., an indication of how

long each of quantum wells 206 should be held in a non-reflective state in order to

encode a single 0 bit, or an indication of the time duration for decoding each signal

received from quantum wells 206.

[0032]   Memory 320 may include a random access memory (RAM) or another

dynamic storage device, a read only memory (ROM) or another type of static storage

device, and/or some other type of magnetic or optical recording medium and its

corresponding drive that stores data for transmission by modulator 310, or that stores data

received from incoming beam 106 and demodulated by demodulator 312. The data may

include an arbitrary message (e.g., the readings of one or more sensor values) or control

traffic (e.g., transmission control protocol (TCP) acknowledgement packets). Memory

320 may also store information and instructions for execution by processor 325.

[0033]   Processor 325 may include any type of conventional processor or

microprocessor that interprets and executes instructions. Processor 325 may control

operation of device 302.

[0034]   Power source 350 may include a battery, fuel cell, solar collector, or any other

device capable of powering components of device 302.

<div align="center">MAC Layer</div>

[0035]   A medium access control (MAC) layer, consistent with the present invention,

governs which device, of a group of devices, has access to a shared medium. In

implementations consistent with the principles of the invention, the shared medium may

be incoming beam 106. In implementations of the invention, the MAC layer may help

govern which one of the retro-reflectors 104 receives incoming beam 106 and a duration

of time that the one of the retro-reflectors 104 receives incoming beam 106. The MAC

layer may allow a proportion of time to be devoted to incoming bits (from probe device

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102 to retro-reflector 104) and a remainder of the time to be devoted to outgoing bits (from retro-reflector 104 to probe device 102). Implementations of the invention allow the proportion to be established as desired, in a flexible manner that may be changed on-the-fly, and that may be different for each of retro-reflectors 104.

[0036] As an example, retro-reflector "A" may receive incoming beam 106 for five milliseconds, then retro-reflector "B" may receive incoming beam 106 for twenty milliseconds, then retro-reflector "A" may receive incoming beam 106 again for five milliseconds, followed by retro-reflector "C", which may receive incoming beam 106 for ten milliseconds, and so forth. Some retro-reflectors 104 may have a relatively large amount of data to send or receive and therefore, may require a relatively large portion of time for receiving incoming beam 106. Other retro-reflectors 104 may have a relatively small amount of data to send or receive and therefore, may require incoming beam 106 less frequently. Some retro-reflectors 104 may require a large proportion of their share of incoming beam 106 to be devoted to incoming data, while other retro-reflectors may require a large proportion of their share of incoming beam 106 to be devoted to outgoing data.

[0037] In some implementations, one or more retro-reflectors 104 may enter a low-power state (go to sleep) when they are not actively sending or receiving in order to extend battery life. Enough information may be provided to retro-reflectors 104, such that each of the retro-reflectors 104 may know when it will be active next. Thus, one or more retro-reflectors 104 may sleep until a next active time.

Exemplary MAC Layer Frame Structure

[0038]   Figs. 4A and 4B illustrate an exemplary MAC layer frame structure, consistent with the present invention. Fig. 4A shows exemplary incoming frame 400, which may be used for communications from probe device 102 to retro-reflector 104 (incoming communications). Fig. 4B shows an exemplary outgoing frame 420, which may be used for communications from retro-reflector 104 to probe device 102 (outgoing communications).

[0039]   As illustrated by Fig. 4A, incoming frame 400 may include a preamble 402, an IA field 404, an OA field 406, an idle-A field 408, an incoming payload field 410 and an IFEC field 412.

[0040]   Preamble 402 may include synchronization patterns that allow retro-reflector 104 to establish bit boundaries of a received message in incoming beam 106. Preamble 402 may also include a probe device identifier, such as a unique identifier of a given probe device 102 and/or an identifier of a given retro-reflector 104.

[0041]   IA field 404 may indicate an incoming actual allocation (i.e., a number of bits retro-reflector 104 may be permitted to receive) to retro-reflector 104.

[0042]   OA field 406 may indicate an outgoing actual allocation (i.e., a number of bits retro-reflector 104 may be permitted to transmit) to retro-reflector 104.

[0043]   Idle-A field 408 may indicate an amount of time until a next frame from probe device 102 for a particular retro-reflector 104. Retro-reflector 104 may use a value of idle-A field 408 to determine how long retro-reflector 104 may sleep.

[0044]   Incoming payload field 410 may include message bits from probe device 102 to retro-reflector 104.

[0045]   IFEC field 412 may be a forward error correction code or checksum that may

cover IA field 404, OA field 406, idle-A field 408 and incoming payload field 410. In

some implementations, IFEC field 412 may also cover other content of frame 400, such

as, for example, the probe device identifier, the retro-reflector identifier, or any other

useful information that may be included in incoming frame 400. The forward error

correction code included in IFEC 412 may include a cyclic redundancy check, a

checksum, or the like.

[0046]   Outgoing frame 420, as illustrated in Fig. 4B, is an exemplary frame format

for communications from retro-reflector 104 to probe device 102 (outgoing

communications). Outgoing frame 420 may include a preamble 422, an ID field 424, an

OD field 426, an idle-D field 428, an outgoing payload field 430 and an OFEC field 432.

[0047]   Preamble 422 may be similar to preamble 402. Alternatively, because

reflected beam 108 may be much weaker than incoming beam 106, preamble 422 may be

quite different from preamble 402. For example, preamble 422 may be much longer than

preamble 402.

[0048]   ID field 424 may indicate an input rate desired by retro-reflector 104, for

example, a number of desired incoming bits requested by retro-reflector 104 for a

subsequent time interval. The time interval may be any amount of time, for example, one

second, one minute, one hour, one millisecond, etc. For example, if the time interval is

one second, then ID field 424 may indicate a number of bits that retro-reflector 104

desires to receive in a coming one second time period.

[0049]   Similar to ID field, 424, OD field 426 may indicate an output rate desired by

retro-reflector 104, for example, a number of bits that retro-reflector 104 may desire to

send in the same subsequent time interval. Idle-D field 428 may indicate a time interval between incoming frames desired by retro-reflector 104. A large value in idle-D field 428 may indicate that retro-reflector 104 desires to communicate less frequently, while a small value may indicate that retro-reflector 104 desires to communicate more frequently.

[0050]   Outgoing payload field 430 may include outgoing message bits from retro-reflector 104 to probe device 102. If the message bits are fewer than an amount of bits allocated for outgoing payload field 430, then outgoing payload field 430 may be, for example, padded with blank values or outgoing payload field 430 may simply be shorter than the allocated length.

[0051]   OFEC field 432 may include a forward error correction. OFEC field 432 may cover ID field 424, OD field 426, idle-D field 428, and outgoing payload field 430. In some implementations, OFEC field 432 may cover portions of preamble 422 or any other useful information included in frame 420. The forward error correction technique employed for OFEC field 432 may be the same technique used for IFEC 412. Alternatively, because reflected beam 108 may be much weaker than incoming beam 106, a different forward error correction technique may be employed.

[0052]   A frame set, as described herein, includes an incoming frame and an outgoing frame sent in response to the incoming frame. For example, probe device 102 may transmit incoming beam 106, including incoming frame 400, to retro-reflector 104, which responds with outgoing frame 420 in reflected beam 108. Incoming frame 400 and outgoing frame 420 sent in response to receiving incoming frame 400, therefore, comprise a frame set. In some implementations, a short "dead" interval may exist between an incoming frame and an outgoing frame of a frame set. The short "dead"

interval may provide retro-reflector 104 with time to switch from a detection (input) mode to a reflection (output) mode. In other implementations, retro-reflectors 104 may be capable of transmitting and receiving data simultaneously (for example, two different frequencies may be present in incoming beam 106). In such implementations, incoming frame 400 and outgoing frame 420, respectively, may be received by and sent from retro-reflector 104, simultaneously, instead of serially.

[0053] In practice, IA field 404 and OA field 406 may not govern payload sizes for a current frame set because of possible hardware timing considerations. Thus, in an alternative implementation, IA field 404 and OA field 406 may govern payload sizes for a next set frame set.

[0054] Different retro-reflectors 104 may employ different types of preambles 402, 422 and/or forward error correction, IFEC 412, OFEC 432. For example, some retro-reflectors 104 may be larger than others or may be in a better position than others. Such retro-reflectors 104 may be able to use shorter preambles 402, 422 and fewer forward error correction bits. The decision may be made based on retro-reflector type or expected location of retro-reflector 104. Alternatively, preambles 402, 422 and forward error correction codes, OFEC 432 and IFEC 412, may be adjusted on demand based, for example, on a detected error rate. For example, all retro-reflectors 104 may begin with very long preambles 402, 422 and forward error correction codes, OFEC 432 and IFEC 412. The length of preambles 402, 422 and forward error correction codes, OFEC 432 and IFEC 412, for all retro-reflectors 104 or for particular ones of retro-reflectors 104 may be shortened or lengthened based on detected error rates of retro-reflectors 104. For example, preambles 402, 422 and forward error correction codes, OFEC 432 and IFEC

412, of retro-reflectors 104 having low detected error rates may be adjusted to be shorter, while preambles 402, 422 and forward error correction codes, OFEC 432 and IFEC 412, of retro-reflectors 104 having a high detected error rate may be adjusted to be longer.

Exemplary Processing

[0055]   Fig. 5 is a flowchart that illustrates exemplary processing for beginning communications among probe device 102 and a group of retro-reflectors 104, consistent with principles of the invention. Probe device 102 may begin by creating a "startup" frame. The "startup" frame may have the form of incoming frame 400 (Fig. 4A) (act 502). The "startup" frame may have no incoming data in incoming payload field 410, but may have a non-zero value in OA field 406 to inform retro-reflector 104 of a permitted output allocation for the next frame set. Further, the "startup" frame may have a non-zero value in idle-A field 408 to inform retro-reflector 104 when retro-reflector 104 will again receive input beam 106, including incoming frame 400, from probe device 102. For example, the "startup" frame may have a value of "1" in idle-A field 408 and a value of "20" in OA field 406. Thus, in this example, retro-reflector 104 may be informed that the next input beam 106 will be received in one time unit (milliseconds, seconds, minutes, hours, etc.) and that retro-reflector 104 will be permitted, in the next frame set, to send an outgoing message up to 20 size units (bits, bytes, blocks, etc.).

[0056]   Probe device 102 may direct incoming beam 106 to a first retro-reflector 104 (act 504) and may send the "startup" frame to that retro-reflector 104 (act 506). Upon receiving an error-free or error corrected (via the forward error correction code) "startup" frame, retro-reflector device 302 may examine idle-A field 408 to determine when retro-reflector 104 will again receive incoming frame 400. Retro-reflector device 302 may also

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examine OA field 406 to determine a size of an outgoing message that retro-reflector 104

is permitted to send in the next frame set and may examine IA field 404 to determine a

size of an incoming message that retro-reflector 104 may receive in the next frame set.

Assuming that the "startup" frame is received without errors or is corrected of errors,

retro-reflector 104 may create and send a "startup response" frame in the form of

outgoing frame 420 (Fig. 4B). The "startup response" frame may not include message

bits in outgoing payload field 430, but may indicate a desired input data rate in ID field

424, a desired output data rate in OD field 426, and a desired time interval until retro-

reflector 104 again receives incoming beam 106 including incoming frame 400. Retro-

reflector device 302 may determine a value for OD field 426 and idle-D field 428 based

on an amount of data that retro-reflector device 302 may have waiting to be transmitted

to probe device 102. Probe device 102 receives the "startup response" frame (act 506).

[0057]   After sending the "startup" frame to a first retro-reflector 104, probe device

102 may determine whether there are any other retro-reflectors 104 to which a "startup"

frame should be sent (act 508). In some implementation, a number of retro-reflectors 104

and corresponding locations may be known in advance. If probe device 102 determines

that there are no additional retro-reflectors 104, then the process is completed.

Otherwise, probe device 102 may direct incoming beam 106 to a next retro-reflector 104

(act 510) and processing continues at act 506.

[0058]   After executing the processing of Fig. 5, probe device 102 has collected

desired output and input allocations for a next time period and a desired time interval

between frames from all retro-reflectors 104. Assuming that a value in idle-A field 406

in the last frame sent to each particular one of retro-reflectors 104 governs the schedule

for the next frame set for each particular one of the retro-reflectors 104, the schedule for

the next round of frames is already determined. However, probe device 102 may create a

new schedule for the following round of frames. Probe device 102 may create the

schedule by taking into account, for example, desired input data from ID field 424 and

desired output data from OD field 426 collected from each of retro-reflectors 104, an

amount of time needed to steer incoming beam 106 from one retro-reflector 104 to

another retro-reflector 104, an incoming beam 106 duty cycle, urgent data that requires

immediate transmission, etc. A resulting schedule may give a number of short intervals

at rapid repetition rates to some retro-reflectors 104, interspersed with longer intervals to

other retro-reflectors 104. Probe device 102 may arbitrarily vary the schedule according

to the needs of individual retro-reflectors 104 and the collection as a whole.

[0059]   Fig. 6 is a flowchart that illustrates exemplary processing that may be

performed consistent with the principles of the invention. Assuming that the processing

described in Fig. 5 has been performed and that probe device 102 created a schedule, as

described above, probe device 102 may begin by consulting the schedule to determine

which one of the retro-reflectors 104 is to be serviced next and when that retro-reflector

104 is to be serviced (act 602). Probe device 102 may then create a new incoming frame

400 (act 604). Probe device 102 may include appropriate values for fields IA 404, OA

406, idle-A 408, and incoming payload 410. The values for fields IA 404, OA 406 may

be derived from the schedule, while incoming payload 410 may be derived by messages

that probe device 102 has that are waiting for delivery to retro-reflector 104.

[0060]   At the scheduled time, probe device 102 may send incoming frame 400 to the

next retro-reflector 104 via incoming beam 106 (act 606). Retro-reflector 104 may then

send a message in outgoing payload field 430 of outgoing frame 420 of a size that may be limited based on the allocated outgoing size limit, as specified by probe device 102 in OA field 406 of incoming frame 400 of an immediately preceding frame 400 sent to retro-reflector 104. Probe 102 may capture the response frame 420 from retro-reflector 104 (act 608). Retro-reflector 104 may set values in fields ID 424, OD 426 and idle-D 428 of outgoing frame 420 according to a desired amount of input, a desired amount of output, and a desired schedule time interval, respectively. Probe 102 may have already determined a next scheduled time interval for retro-reflector 104 as indicated by the value of idle-A field 408 of incoming frame 400 sent to retro-reflector 104. Probe device 102 may consider the values of fields ID 424, OD 426 and idle-D 428 of frame 420 of the current received frame 420 when scheduling a future interval, for example, the interval after the next interval (act 610). Probe device 102 may again perform acts 602-610 for a next scheduled retro-reflector 104.

[0061] In implementations consistent with the principles of the invention, the schedule may be recalculated after every frame set. Consequently, the access control scheme may be highly responsive to events. For example, if a sensor attached to retro-reflector 104 detects something of interest, retro-reflector 104 may request a schedule change from a relatively leisurely schedule, for example, a few bits every ten seconds, to a much more demanding schedule, such as, for example, 10,000 bits every second. Retro-reflector 104 may request the schedule change by indicating the desired schedule change via idle-D field 428, and the desired data rate change via ID field 424 and OD field 426.

Conclusion

[0062]   Systems and methods consistent with the principles of the invention perform a medium access control scheme for organizing and scheduling sending and receiving of messages between a probe device and each retro-reflector from a group of retro-reflectors. According to exemplary embodiments, each retro-reflector device may sleep until a next scheduled time for receiving an incoming beam from the probe device. The received incoming beam may have data encoded and modulated onto the beam. The retro-reflector may sense this data, which may include scheduling information for a later communication with probe device 102. When the retro-reflector device receives the incoming beam, the retro-reflector may receive an incoming message and may send an outgoing message, along with desired scheduling information and desired input and output rate information, which may be considered by the probe device when recalculating a new schedule.

[0063]   The foregoing description of preferred embodiments of the invention provides illustration and description, but is not intended to be exhaustive or to limit the invention to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention. For example, while a series of acts have been described with regard to Figs. 5-6, the order of the acts may differ in other implementations consistent with the present invention. Also, non-dependent acts may be performed in parallel. Further, the acts of Figs. 5-6 are exemplary. In some implementations, consistent with the present invention, some of the acts may be omitted, while in other implementations, additional acts may be included. In addition, certain portions of the invention may be implemented as "logic" that performs

one or more functions. This logic may include hardware, such as an application specific integrated circuit, a field programmable gate array and/or a microprocessor, software, or a combination of hardware and software.

[0064]   No element, act, or instruction used in the description of the present application should be construed as critical or essential to the invention unless explicitly described as such. Also, as used herein, the article "a" is intended to include one or more items. Where only one item is intended, the term "one" or similar language is used. The scope of the invention is defined by the claims and their equivalents.